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# AN OPTIMIZED APPROACH FOR SYMMETRIC FACE RECOGNITION USING EIGEN FACES

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## ABSTRACT

Eigen face approach is one of the earliest face recognition approach introduced in the year 1991 by M. Turk and A. Pentland. It is a Principal Component Analysis (PCA) based approach. Initially, PCA decomposes the face image into a small set of characteristic features known as eigen faces, followed the computation of distance between the resultant position in the face space and the known face classes. This analysis reduces the dimensionality of the training set, leaving only those features that are critical for face recognition. An important factor in the eigen face approach is, choosing a threshold value that influences the process of face recognition. Eigen face has proven to be highly useful and robust approach for face recognition, localization and tracking.

**KEYWORDS:** Symmetric Face Recognition Using Eigen Faces, PCA

## INTRODUCTION

Eigen faces are set of eigen vectors used in computer vision problem of human face recognition. These eigen vectors are derived from the co-variance matrix of the probability distribution of high dimensional vector space of possible faces of human beings. Eigen face approach is one of the simplest and most efficient methods in developing a system for face recognition. They refer to an appearance based approach to face recognition that seeks to capture the variation in a collection of face images and use this information to encode and compare images of individual face. In, eigen face approach, after the dimensional reduction of the face space, the distance is measured between two images for recognition. If the distance is less than the chosen threshold value, then it is considered as a known face, else it is an unknown face. Since the initial development of eigen face approach, there have been many extensions to the original method. Post these developments still eigen face is considered as a base line comparison method to demonstrate the minimum expected performance of a system. The two prevalent cases where eigen face approach is being used are, to

- Extract the relevant facial information which may are may not be directly related to human intuition of face features such as eyes, nose and lips. This extraction could be done by capturing the statistical variation between face images
- Represent face images efficiently by representing each face image using a small number of dimensions, the computation and space complexity can be minimized

In the training process of the approach the face database is created and a projection matrix of low dimension is obtained from all the face images in the database followed by the calculation of mean face and the reduced representation

of each database image with respect to the mean face is calculated. The calculated representations are the ones that are used in the process of recognition. The basic steps involved in face recognition using the eigen faces approach are as follows

**Initialization**

- Acquire training set, a set of initial face images.
- Calculate Eigen faces from the first M images of highest eigen values in the training set.
- Calculate distribution in M-dimensional space by projecting the respective face image of each known person onto this face space.

**Recognizing New Face Images**

- Calculate a set of weights for the given input image based on M eigen faces by projecting this new image onto each of the eigen faces.
- Determine whether the image is known face or not by checking whether its Euclidean distance with other images is less than some threshold value or not.
- Update the eigenfaces as either known or unknown. If the same unknown face is seen several times then calculate the characteristic weight pattern and incorporate into new faces.

The step (iii) is optional and can be implemented when there is a requirement. M. Kirby and L. Sirovich have shoen that any particular face could be economically represented in terms of a best co-ordinate system which was termed “Eigen faces”. Turk and Pentland proposed and successfully implemented a eigen face based face recognition which is motivated by information theory. Nayar and Murasae utilized an eigen space approach to represent and recognize general 3D objects at various poses, formulating object and pose recognition as parameterized appearance matching.

Eigen face algorithm is applied on variety of images taken under different lighting conditions and different backgrounds.

The face images also undergo changes with respect to the facial expression, age, view point, illumination conditions, noise and pose. The task of face recognition system is to recognise a face independently besides these variations.

**Flow Chart**

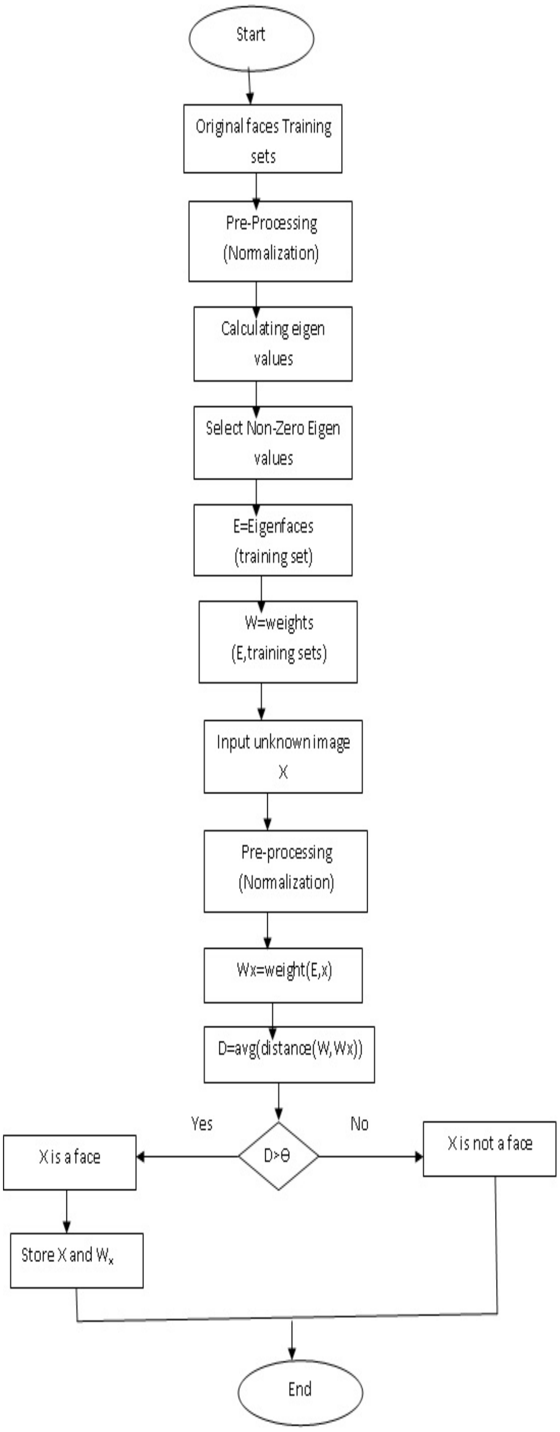


**Figure 1**

## ALGORITHM

### Creating Eigen Faces

- Prepare a training set of face images taken under same lighting conditions and must be normalised to have the eyes and mouth aligned across all images. Also the images must be re sampled to the same pixel resolution.
  Let the training set of face images be $\Gamma_1\Gamma_2.....\Gamma_M$

Each picture has R rows and C columns.

- Convert each picture in the training set into a vector of length RxC. Vector is formed by concatenating the rows of pixels of the original image.
- If there are n training set images, then create a matrix M with N number of rows where each row is of length RxC. Each row will be represented by one of the image vectors. These vectors are known as orthonormal vectors $u_k$, which best describes the distribution of data. The Kth vector $u_k$ is chosen such that

$$\lambda_k = \frac{1}{M}(u_k^T \phi_n)^2$$

- Calculate the mean image A of N image vectors. Subtract A from each row of M to obtain the matrix T. The mean face of the set is defined by

$$\Psi = \frac{1}{M} \Sigma\Gamma_k$$

Each face differs from the average by the vector

$$\phi_i = \Gamma_i - \Psi$$

- The co-variance matrix, S is given by S= T’. T where T’ represents the transpose matrix of T.

$$S = \frac{1 \sum_{n=1}^{M} \phi . \phi T}{M}$$

$$= A.A^T$$

Where the matrix A= [$\phi_1,\phi_1,\phi_1....\phi_M$ ]

- Calculate the Eigen vectors and Eigen values of S. The vectors $u_k$ and $\lambda_k$ scalars of equation are the eigen vectors and eigen values respectively of the covariance matrix.

The covariance matrix S has a dimensionality of $N^2 \times N^2$, so one would have $N^2$ eigenfaces and eigenvalues. For example a 256 × 256 image that means that one must compute a 65, 536 × 65, 536 matrix and calculate 65, 536 eigenfaces.

RxC number of eigen vectors has been obtained. But the main objective of PCA is to store only the eigen vectors with the highest value. These eigen faces can be used to represent both the existing and the new faces. A new (mean subtracted) image has been projected on the eigen faces and there by records the difference of new face from mean face. The Eigen values associated with each eigen face represents the variation between the images in the training set and the mean image.

**Recognising Eigen Faces**

- Obtain a test image I
- Subtract the mean image A from the test image

  D = I-K.

- Find its projection on the face space

  P = eigen faces * D

- Find the Euclidean distances of this projection to the projection of images already in the face space. Find the lowest Euclidean distance. If this distance is lower than a pre-determined threshold then it is a successful match

else it's a failure.

- Optionally if face image occurs multiple times but is not found within the training database it may be added to the database and the eigen vectors may be recomputed.

Generally threshold value is chosen arbitrarily. There is no specific formula for calculating the threshold value. Sometimes the arbitrarily chosen values may be taken as some factor of maximum value of minimum Euclidean distance of each image from other images

Recognition process can be formulated as,

- If $\varepsilon \geq \Theta\varepsilon$ then input image is not a face.
- If $\varepsilon < \Theta\varepsilon, \varepsilon_k \geq \Theta\varepsilon$, then input image contains an unknown face.
- $\varepsilon < \Theta\varepsilon, \varepsilon_k = \min\{\varepsilon_k\} < \Theta\varepsilon$, then image contains face of individual k'.

To summarize the process of Face Recognition in Eigenface approach, the training set of images are given as input to find eigenspace. Using those images, the average face image is computed. The difference of these images is represented by covariance matrix. It is used to calculate Eigen vectors and Eigen values. Those are the Eigenfaces which represent various face features. Sort the eigen values obtained, and consider the highest of them, since they represent maximum variations. It becomes eigenspace spanned by the eigenfaces that has lower dimension than original images. The two given test images are projected onto this eigen space to give the weight vector also known as Face key for that image. The Euclidean distance between these two face key vectors is calculated. If this is below some threshold value, then two images are said to be matching that means they belong to same person. On result being False, the False Acceptation Rate (FAR) and False Rejection Rate (FRR) are found. These are used to change the value of Threshold. In this way Face Recognition is carried out using Eigenface Approach.

From the observations and graph it is clear that if the threshold value is taken as 0.6 times of the maximum value of minimum Euclidian distances of each image from other images ie($\theta$ = max(e), recognition rate is more in every observation as compared to the case when threshold is taken as maximum value of minimum Euclidian distance ie. $\theta$ = 0.6*max(e).

It is found to be clear from the observations that as the number of eigen faces increases recognition rate also increases.

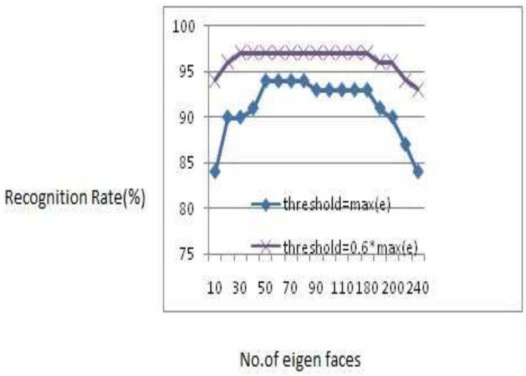


**Figure 1**

**Table 1**

| No. of Eigen Faces | θ = Max(e) | θ = 0.6* Max(e) |
|---|---|---|
| | Recognition Rate (%) | Recognition Rate (%) |
| 10 | 84 | 94 |
| 20 | 90 | 96 |
| 30 | 90 | 97 |
| 40 | 91 | 97 |
| 50 | 94 | 97 |
| 60 | 94 | 97 |
| 70 | 94 | 97 |
| 80 | 94 | 97 |
| 90 | 93 | 97 |
| 100 | 93 | 97 |
| 110 | 93 | 97 |
| 150 | 93 | 97 |
| 180 | 93 | 97 |
| 190 | 91 | 96 |
| 200 | 90 | 96 |
| 220 | 87 | 94 |
| 240 | 84 | 93 |

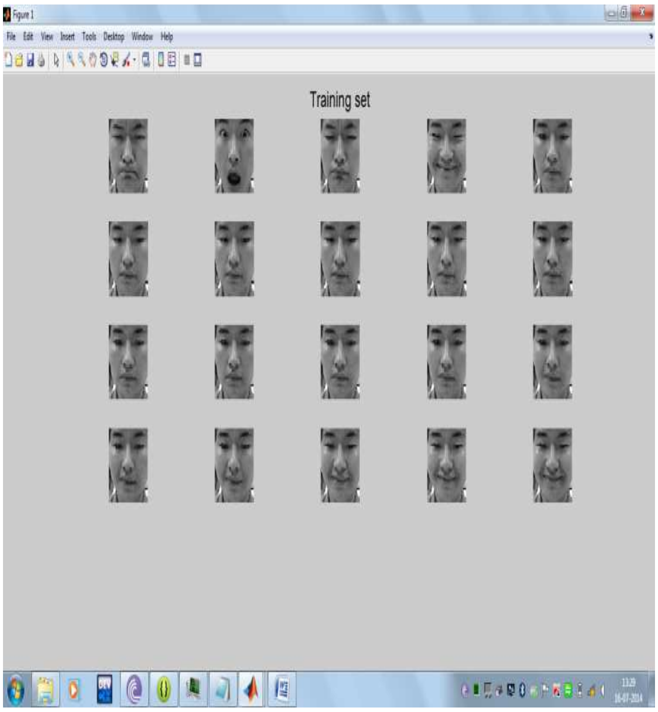


**Figure 2: Training Set of Original Image**

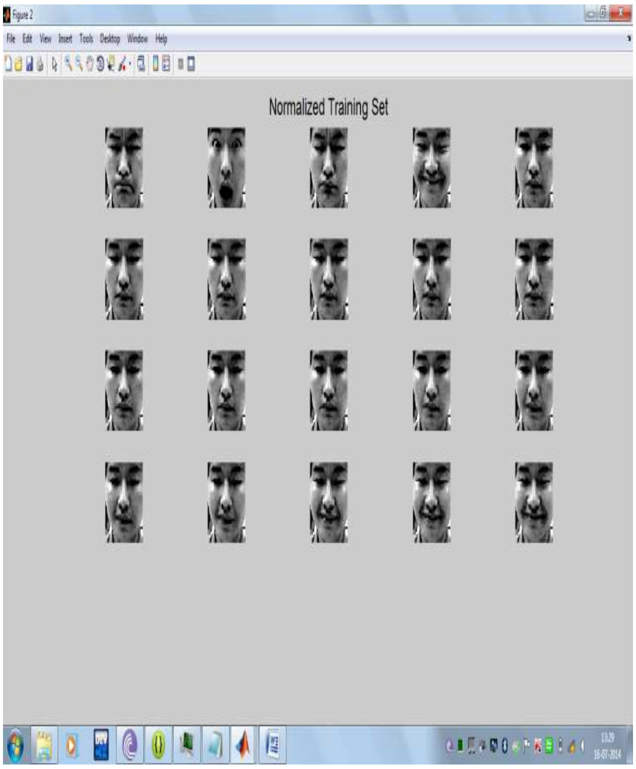


**Figure 3: Normalized Training Set**

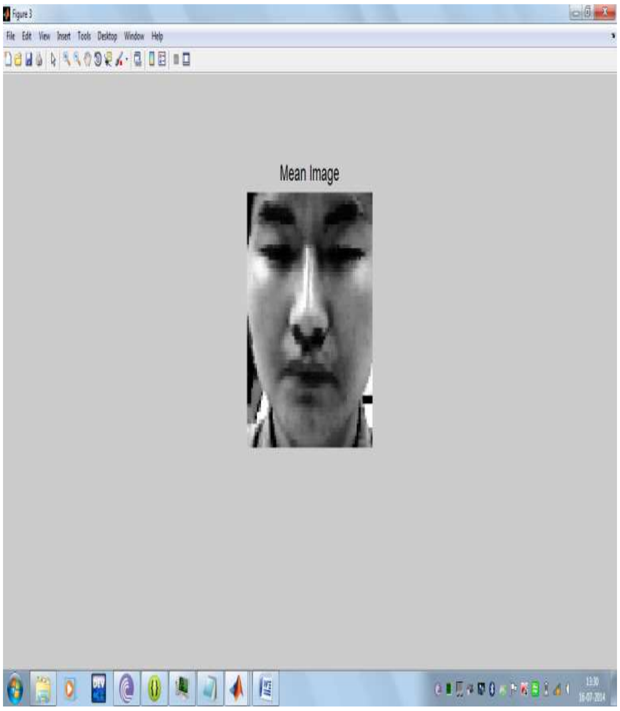


**Figure 4: Mean Image**

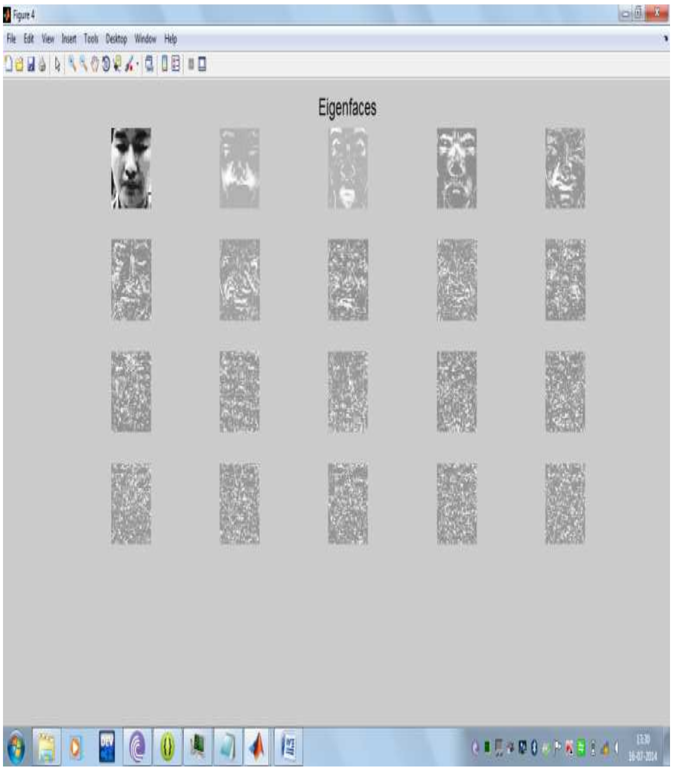


**Figure 5: Eigen Faces of Training Set**

## CONCLUSIONS

In reality, all the images in a given set are closely related and actually span a lower dimensional space. By using eigen face approach, this dimensionality is further reduced. Any new image can be expressed as linear combination of these eigenfaces. This makes it easier to match any two images and thus the process of face recognition. However, this approach is sensitive to images with uncontrolled illumination conditions. Inspiteofit, Highest recognition rate is achieved when 15% of eigenfaces are taken with threshold value equal to 0.6 times of the maximum value of minimum Euclidian distances. A recognition rate of 97% is achieved.

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